# EXECUTIVE SUMMARY

The Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy (DOE) leads the Federal Government's efforts to provide reliable, affordable, and environmentally sound energy for America, through its 11 research, development, demonstration, and deployment (RDD&D) programs. EERE invests in high-risk, high-value research and development (R&D) that, conducted in partnership with the private sector and other government agencies, accelerates the development and facilitates the deployment of advanced clean energy technologies and practices. EERE designs its RDD&D activities to improve the Nation's readiness for addressing current and future energy needs.

This document summarizes the results of the benefits analysis of EERE's programs, as described in the FY 2006 Budget Request. EERE has adopted a benefits framework developed by the National Research Council (NRC)[1] to represent the various types of benefits resulting from the energy efficiency technology improvements and renewable energy technology development supported by EERE programs. Specifically, EERE's benefits analysis focuses on three main categories of energy-linked benefits—economic, environmental, and security. The specific measures or metrics of these benefits estimated for FY 2006 are identified in **Table ES.1**. These metrics are not a complete representation of the benefits or market roles of efficiency and renewable technologies, but provide an indication of the range of benefits provided. EERE is continuing to take steps to more fully represent the NRC framework.[2]

**Table ES.1. EERE FY 2006 Benefits Metrics**

| | |
|---|---|
| **Primary Outcome** | |
| Energy displaced | • Reductions in nonrenewable energy consumption (quadrillion Btu/yr) |
| **Resulting Benefits** | |
| Economic | • Reductions in consumer energy expenditures (NEMS-GPRA06 - billion 2002 dollars/yr)<br>• Reductions in energy-system costs (MARKAL-GPRA06 - in billion 2002 dollars/yr) |
| Environmental | • Reductions in carbon dioxide emissions (mmtc equivalent/yr) |
| Security | • Reductions in oil consumption (mbpd)<br>• Reductions in natural gas consumption (quadrillion Btu/yr)<br>• Avoided additions to central conventional power[3] (cumulative gigawatts) |

- **Table ES.2** shows the estimated energy displaced and resulting benefits to the Nation of realizing the EERE program goals associated with the FY 2006 budget request. These impacts are the benefits expected in the reported year—that is, the benefits are annual, not cumulative (with the exception of avoided additions to conventional central power).

[1] *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*, National Research Council (2001). The NRC is the principal operating agency of the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE), providing services to the government, the public, and the scientific and engineering communities.

[2] In FY 2005, EERE made two key improvements: (1) adding an electricity security metric and (2) extending the analysis through the year 2050. EERE will be implementing additional portions of the framework in the future.

[3] Central conventional power includes centrally located fossil, nuclear, combined cycle, combustion turbine/diesel, and pumped storage. It does not include distributed power and renewable power (central or distributed).

**Table ES.2. Summary of Annual EERE Integrated Portfolio Benefits for FY 2006 Budget Request[4,5]**

| EERE Midterm Benefits (NEMS-GPRA06) | 2010 | 2015 | 2020 | 2025 |
|---|---|---|---|---|
| Energy Displaced | | | | |
| • Primary nonrenewable energy savings (quadrillion Btu/yr) | 1.1 | 3.4 | 7.8 | 12.3 |
| Economic | | | | |
| • Energy-expenditure savings (billion 2002 dollars/yr)* | 12 | 37 | 87 | 123 |
| Environment | | | | |
| • Carbon dioxide emission reductions (mmtc equivalent/yr) | 22 | 67 | 160 | 262 |
| Security | | | | |
| • Oil savings (mbpd) | 0.1 | 0.6 | 1.3 | 2.3 |
| • Natural gas savings (quadrillion Btu/yr) | 0.5 | 1.1 | 1.9 | 1.8 |
| • Avoided additions to central conventional power (cumulative gigawatts)[6] | 5 | 49 | 96 | 137 |

| EERE Long-Term Benefits (MARKAL-GPRA06) | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| Energy Displaced | | | | |
| • Primary nonrenewable energy savings (quadrillion Btu/yr) | 8.0 | 17.7 | 28.2 | 33.6 |
| Economic | | | | |
| • Energy-system cost savings (billion 2002 dollars/yr)* | 43 | 102 | 188 | 282 |
| Environment | | | | |
| • Carbon dioxide emission reductions (mmtc equivalent/yr) | 152 | 364 | 568 | 699 |
| Security | | | | |
| • Oil savings (mbpd) | 1.3 | 4.6 | 9.0 | 11.0 |
| • Natural gas savings (quadrillion Btu/yr) | 3.1 | 2.8 | 3.6 | 2.4 |

* Midterm energy-expenditure savings only include reductions in consumer energy bills, while long-term energy-system cost savings also include the incremental cost of the advanced energy technology purchased by the consumer.

Under a business-as-usual energy future, realization of these goals and the associated projected market outcomes would:

- Reduce the expected increase in U.S. energy demand by 39% in 2025 and 76% in 2050, resulting in a reduction in nonrenewable energy consumption starting in 2030. (**Figure ES.1**)
- Reduce the expected increase in U.S. consumer energy expenditures by 43% in 2025. (**Figure ES.2**)
- Reduce the expected increase in U.S. energy system costs by 6% in 2050. (**Figure ES.3**)
- Reduce the expected increase in annual U.S. carbon emissions by 45% in 2025 and 71% in 2050. (**Figure ES.4**)
- Reduce the expected increase in U.S. oil consumption (most of which is expected to originate from outside the United States) by 34% in 2025 and 98% in 2050, resulting in declining oil consumption after 2025. (**Figure ES.5**)

[4] Estimates reflect the benefits associated with program activities from FY 2006 to the benefit year, or to program completion (whichever is nearer), and are based on program goals developed in alignment with assumptions in the president's budget. Midterm program benefits were estimated using the NEMS-GPRA06 model, based on the Energy Information Administration's (EIA) National Energy Modeling System (NEMS) and using the EIA's *Annual Energy Outlook 2004* (*AEO2004*) Reference Case. Long-term benefits were estimated using the MARKAL-GPRA06 model developed by Brookhaven National Laboratory. Results can differ among models due to structural differences. The models used in this analysis estimate economic benefits in different ways, with MARKAL reflecting the cost of additional investments required to achieve reductions in energy bills.

[5] For some metrics, the benefits estimated by MARKAL-GPRA06 do not align well with those reported by NEMS-GPRA06. Every attempt is made in the integrated modeling to use consistent baselines, input data and assumptions in both models to produce consistent results. However, NEMS and MARKAL are in some respects fundamentally different models (see Boxes 4.1 and 5.1). Discrepancies in the estimated benefits often exist simply because of these model differences.

[6] Small final changes in these estimates were not reflected in the FY 2006 Budget Request.

- Reduce the expected increase in U.S. natural gas consumption, much of which is expected to originate outside the United States, by 21% in 2025 and 18% in 2050. (**Figure ES.6**)
- Reduce the need for additions to central conventional power by 16% in 25. (**Figure ES.7**)

EERE develops these benefits projections annually to help meet the requirements of the Government Performance and Results Act (GPRA) of 1993 and the President's Management Agenda (PMA). GPRA requires Federal Government agencies to develop and report on output and outcome measures for each program. This analysis helps meet GPRA requirements by identifying the potential outcomes and benefits of realizing EERE program goals (outputs). The benefits estimates do not reflect the risk of realizing these goals, which is being addressed separately.[7]

The reported benefits reflect only the net annual improvement from 2005 to 2050 of program activities included in EERE's FY 2006 Budget Request (including subsequent-year funding) and do not include the benefits from past work. The benefits estimates assume continued funding for program activities consistent with multiyear program plans.[8] By basing estimated benefits on budget levels, the analysis addresses the performance-budget integration goal of the PMA. This analysis also provides the benefits called for in the R&D Investment Criteria, developed by the Office of Management and Budget (OMB) as part of the PMA.

EERE uses two energy-economy models—NEMS-GPRA06 and MARKAL-GPRA06—to estimate the impacts of EERE programs on energy markets. The NEMS-GPRA06 model is a modified version of the National Energy Modeling System (NEMS), the midterm energy model used by the Department of Energy's Energy Information Administration (EIA). The MARKAL-GPRA06 model is a modified version of the MARKet ALlocation (MARKAL) model developed by Brookhaven National Laboratory and used by numerous countries worldwide. EERE uses NEMS-GPRA06 to estimate the midterm benefits of its programs and MARKAL-GPRA06 to estimate the long-term benefits of its programs. Descriptions of these models are provided in **Chapters 4 and 5**.

EERE uses a three-step process to estimate benefits across its portfolio:

(1) Establishment of the Baseline Case and guidance
(2) Determination of program and market inputs
(3) Assessment of program and portfolio benefits.

In **Step 1**, a Baseline Case and standard methodological approach (guidance) are developed to improve the consistency of estimates across EERE programs. The Baseline Case provides a representation of business-as-usual future energy markets without the effect of EERE programs. It also provides a consistent set of assumptions about future energy prices, conversion factors, economic growth, and other external factors, against which to analyze the impacts of EERE programs. To develop the Baseline Case through 2025, EIA's *Annual Energy Outlook 2004* (*AEO2004*) Reference Case forecast is modified to remove any identifiable effects of EERE

[7] A standard approach to risk assessment is being developed for EERE's multiyear program plans.
[8] Funding levels may increase, decrease, or remain constant, depending on the program. See Appendices B through M for information on individual multiyear program plans.

programs already included in the forecast. This is done for both the NEMS-GPRA06 model and the MARKAL-GPRA06 model.[9]

For the period after 2025, other credible sources are used to compile a set of economic and technical assumptions for MARKAL-GPRA06.[10] A summary of the Baseline Case results is included in **Appendix A**. EERE also specifies common methodological approaches (guidance) used in developing benefits estimates. This guidance identifies common definitions, the basis for assessing benefits, data requirements, etc. An overview is provided in **Chapter 2**.

In **Step 2**, analysts from throughout EERE characterize the results of the EERE programs in a format suitable for analysis within the NEMS and MARKAL integrated-modeling frameworks. For technology R&D programs, this usually requires expressing program outputs in terms of the cost and performance of a new (or improved) technology, which will compete against an existing, but improving, technology in the baseline. For deployment programs (*e.g.*, information dissemination, or codes and standards), analysts develop approaches to characterizing outputs on a case-by-case-basis using alternative modeling techniques such as altering discount rates or fixing market penetration (in the case of minimum efficiency standards). In many cases, the NEMS and MARKAL frameworks are not suitable for directly analyzing programmatic activities; as a result, "off-line" analyses are conducted. The market analyses and off-line estimates used in the integrated modeling framework are documented in **Appendices B through M.**

In **Step 3**, the program- and market-specific information from **Step 2** is incorporated into NEMS-GPRA06 and MARKAL-GPRA06. Modeling all the activities within a program together accounts for market feedbacks and interactions that can change the ultimate level of energy savings associated with realizing each program's goals. EERE adjusts off-line estimates to account for areas of overlapping program impacts. This downward revision is based on how much of the overlap or integration was captured by the off-line analysis. The benefits analysis team, based on its expert judgment, determines the amount of revision. The resulting benefits estimates of individual program analyses are listed by program, along with FY 2006 program budgets, in **Table ES.3**.

Analysts also run NEMS-GPRA06 and MARKAL-GPRA06 with all programs simultaneously represented, in order to derive estimates of the benefits of the overall EERE portfolio. This portfolio analysis accounts for interactions among EERE's programs, and tends to report reduced benefits compared to the sum of the individual programs. The fully integrated results are listed in **Table ES.2** and displayed in the graphs in this **Executive Summary**. Specific details on the representation of program outputs in NEMS-GPRA06 and the underlying program analysis and documentation are provided in **Chapter 4**. Representation of the program outputs in MARKAL-GPRA06 is provided in **Chapter 5**.

EERE is continuing to pursue a number of improvements to its benefits analysis. Important changes planned for analysis of the benefits of the FY 2007 budget request include:

[9] Slight differences in the NEMS-GPRA06 and MARKAL-GPRA06 baselines may occur from the differences inherent in the two models.

[10] For instance, the primary economic drivers of Gross Domestic Product (GDP) and population are based on the real GDP growth rate from the Congressional Budget Office's Long-Term Budget Outlook and population growth rates from the Social Security Administration's *2002 Annual Report* to the board of trustees.

- Developing alternative scenarios that reflect potential options facing the Nation in the future (*e.g.*, higher fossil fuel prices, a carbon-constrained world).
- Potential incorporation of new metrics for security and knowledge benefits.
- Greater streamlining and consistency in the development of program-level benefits estimates.

In addition, EERE is developing methods for linking estimates of benefits from both past and future program efforts into the overarching NRC benefits framework noted above. Finally, EERE is developing a more systematic way of representing program and technology risk. Although not part of this benefits analysis *per se*, information on risk is recognized as an important component in the application of benefits information to portfolio management.

**Table ES.3. U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE): FY 2006 Funding Summary and Selected 2025 and 2050 Benefits by Program[11]**

| Program | FY 2006 Request (thousands $) | Nonrenewable Energy Displaced (quads/yr) | | Energy Expenditure Savings (billions 2002$/yr) | | Energy System Cost Savings (billions 2002$/yr) | | Carbon Dioxide Emissions Reductions (million mtce/yr) | | Oil-Use Reductions (mbpd) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2025 | 2050 | 2025 | 2050 | 2025 | 2050 | 2025 | 2050 | 2025 | 2050 |
| Biomass | 72,164 | 0.1 | 1.1 | 0.0 | N/A | N/A | 0.6 | 3 | 19 | 0.0 | 0.4 |
| Building Technologies | 57,966 | 1.2 | 4.2 | 11.5 | N/A | N/A | 62.4 | 28 | 92 | 0.0 | 0.1 |
| Distributed Energy Resources | 56,629 | 0.3 | 0.3 | 1.6 | N/A | N/A | 1.4 | 11 | 4 | 0.0 | 0.0 |
| Federal Energy Management | 19,166 | 0.1 | 0.1 | 0.5 | N/A | N/A | 3.6 | 1 | -0 | 0.0 | 0.0 |
| Geothermal Technologies | 23,299 | 0.3 | 2.4 | 0.0 | N/A | N/A | 5.2 | 8 | 59 | 0.0 | 0.0 |
| Hydrogen, Fuel Cells, and Infrastructure Technologies | 182,694 | 0.2 | 4.3 | 2.4 | N/A | N/A | 26.4 | 5 | 60 | 0.2 | 2.7 |
| Industrial Technologies | 56,489 | 2.2 | 0.5 | 12.9 | N/A | N/A | 3.2 | 44 | 8 | 0.2 | -0.0 |
| Solar Energy Technologies | 83,953 | 0.3 | 1.7 | 1.8 | N/A | N/A | 2.3 | 8 | 36 | 0.0 | 0.0 |
| Vehicle Technologies[12] | 165,943 | 4.0 | 18.9 | 60.9 | N/A | N/A | 177.4 | 76 | 365 | 1.8 | 8.8 |
| Weatherization and Intergovernmental | 310,067 | 1.2 | 1.1 | 9.6 | N/A | N/A | 17.1 | 27 | 23 | 0.1 | 0.1 |
| Wind and Hydropower | 44,749 | 3.3 | 3.7 | 4.5 | N/A | N/A | 3.6 | 81 | 87 | 0.1 | 0.0 |
| Facilities and Infrastructure | 16,315 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| Program Direction and Management Support | 110,980 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A |
| **Sum of programs **** | **1,200,414** | **13.1** | **38.3** | **105.7** | **N/A** | **N/A** | **300.4** | **292** | **753** | **2.3** | **12.** |

** The sum of program benefits differs from the EERE portfolio values in Table ES.2, because interactions among programs are not accounted for in the individual estimates. Sums may not total due to rounding.

[11] Budget request from *FY 2006 Budget-in-Brief*, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/office_eere/pdfs/fy05_budget_in_brief.pdf.

[12] The Vehicle Technologies Program is run by the Office of FreedomCAR and Vehicle Technologies.

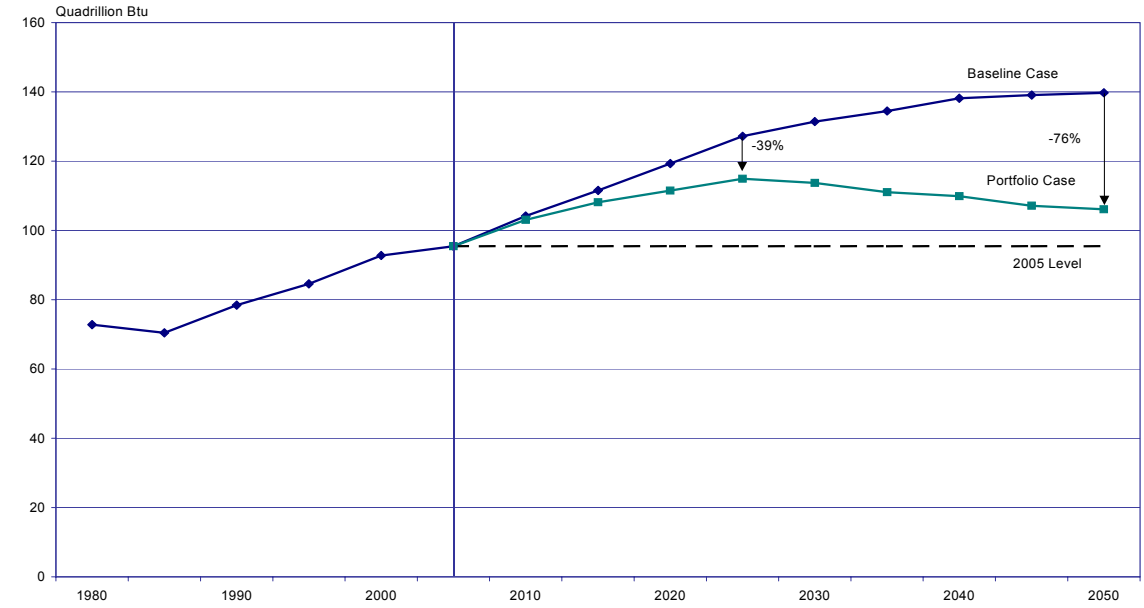


**Figure ES.1. U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases**

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025: NEMS-GPRA06; 2030-2050: MARKAL-GPRA06.

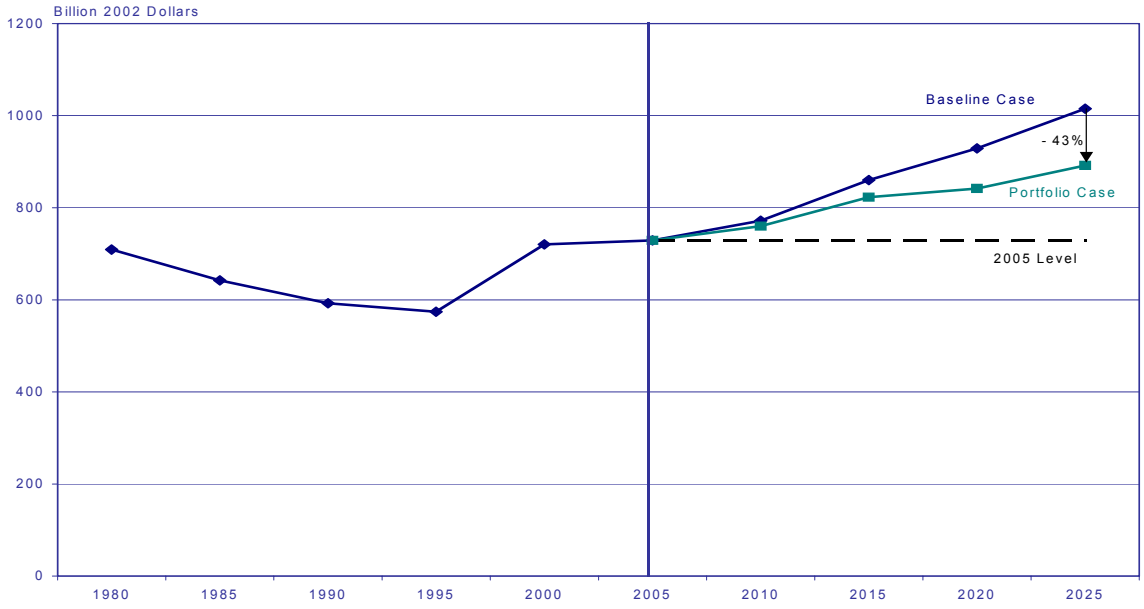


**Figure ES.2. U.S. Total Energy Expenditures, 1980-2000, and Projections to 2025: Baseline and Portfolio Cases**

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 3.4 and Table D1, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025: NEMS-GPRA06; 2030-2050: MARKAL-GPRA06.

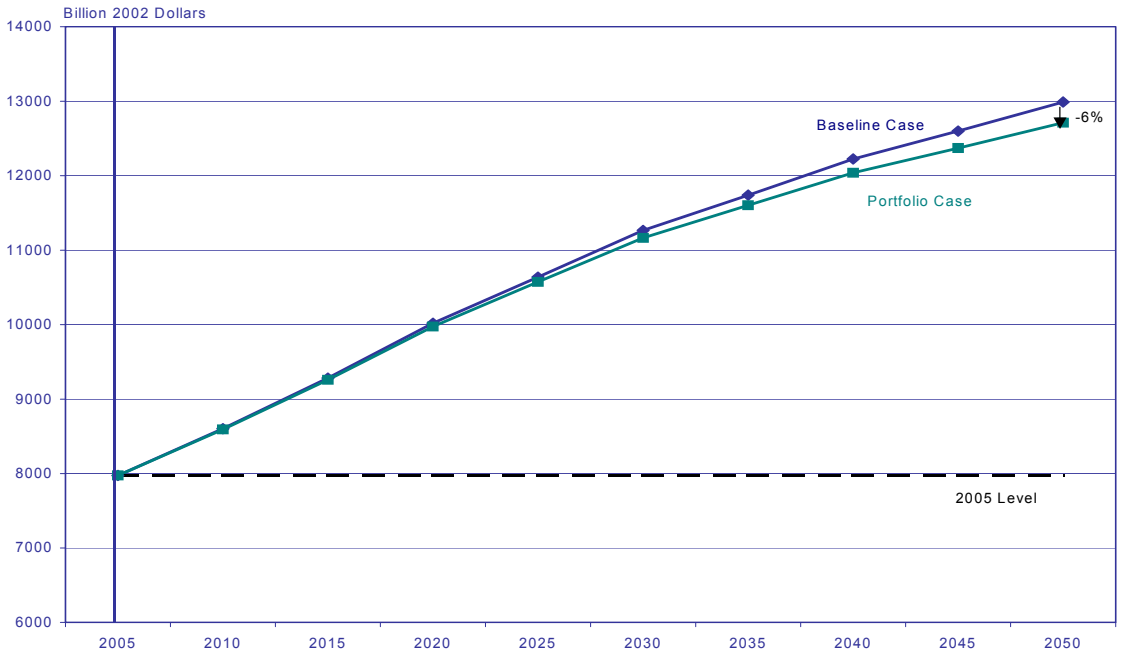


**Figure ES.3. U.S. Total Energy-System Cost Projections to 2050: Portfolio Case**

Note: The percentage change in the chart shown for 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2050 versus 2005. Data Source: MARKAL-GPRA06.

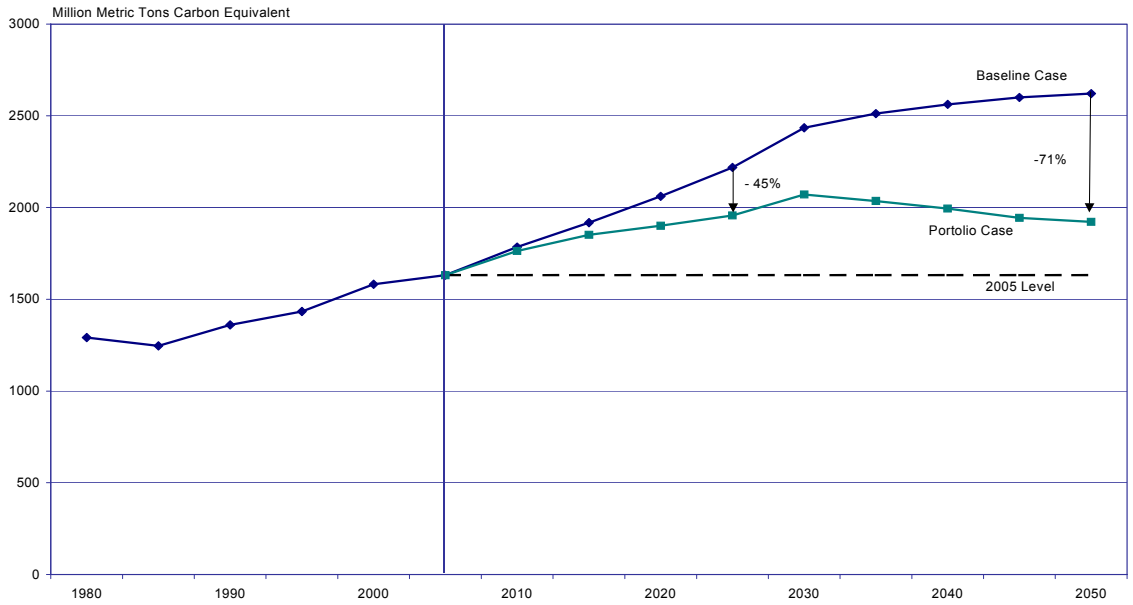


**Figure ES.4. U.S. Carbon Emissions, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases**

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, Energy Information Administration, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 12.2, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA06; 2030-2050, MARKAL-GPRA06.

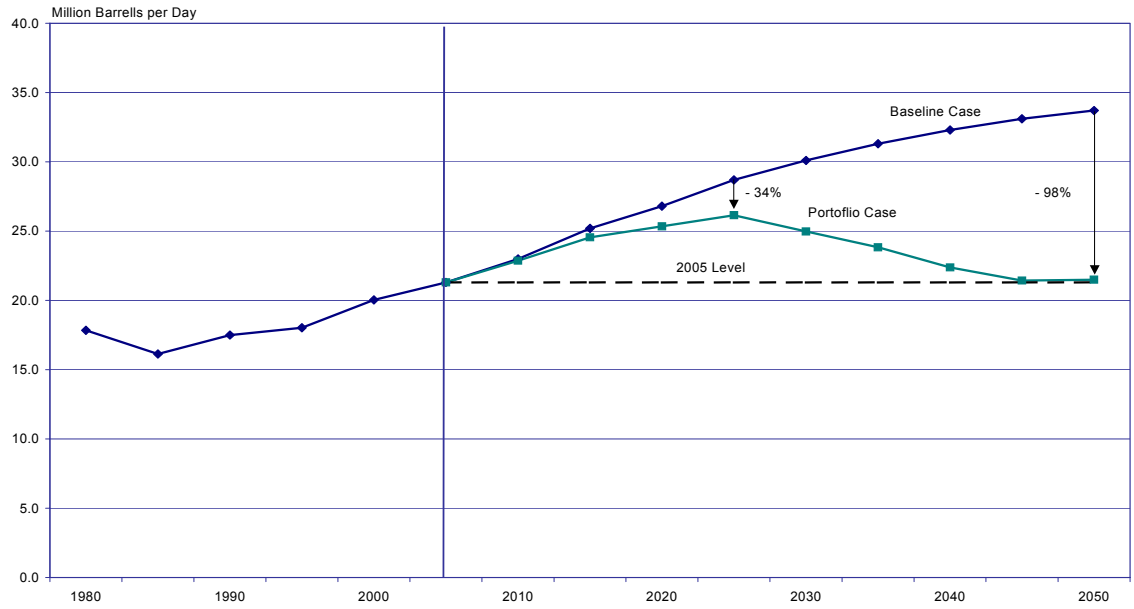


**Figure ES.5. U.S. Oil Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases**

Note: The percentage change in the chart shown for 2025 and 2050 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 (or 2050) versus 2005. Data Sources: 1980-2000, EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA06; 2030-2050, MARKAL-GPRA06.

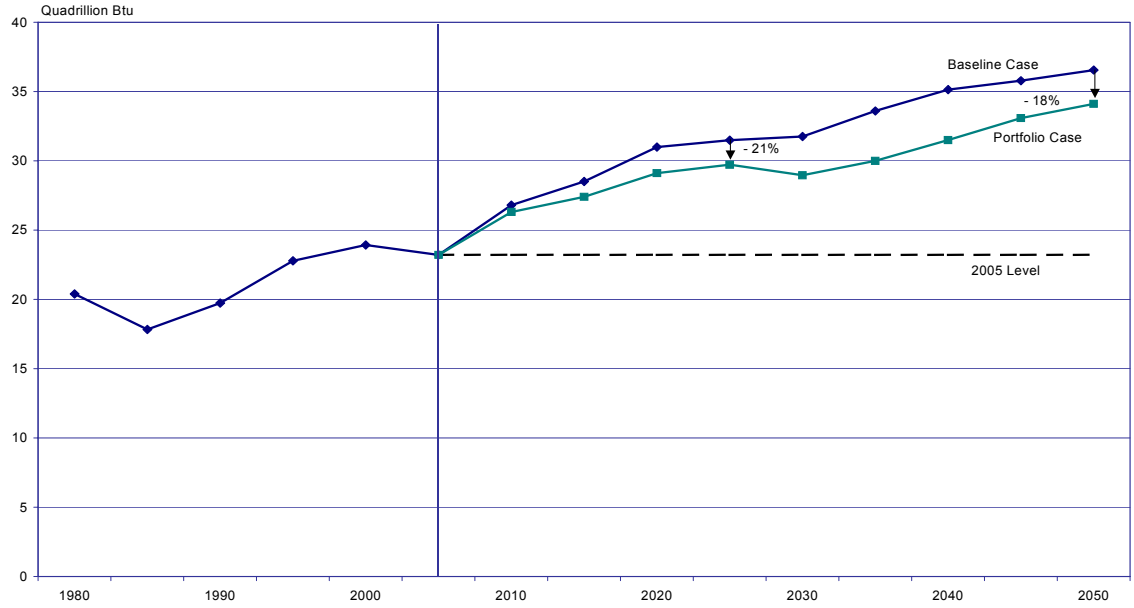


**Figure ES.6. U.S. Natural Gas Consumption, 1980-2000, and Projections to 2050: Baseline and Portfolio Cases**

Data Sources: 1980-2000, EIA, *Annual Energy Review 2003*, DOE/EIA-0384 (2003), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2005-2025, NEMS-GPRA06; 2030-2050, MARKAL-GPRA06.

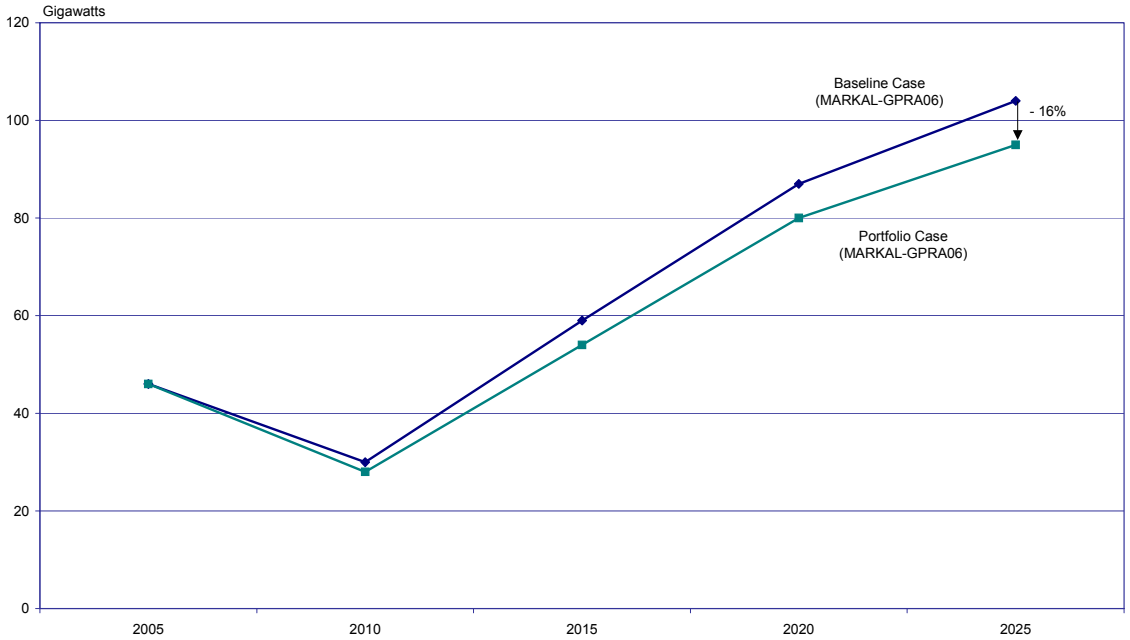


**Figure ES.7. U.S. Central Conventional Electricity-Capacity Addition Projections to 2025: Baseline and Portfolio Cases**

Note: The percentage change in the chart shown for 2025 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2025 versus 2005. Data Source, MARKAL-GPRA06.